Comment on "Critical currents in ballistic two-dimensional InAs-based superconducting weak links"

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Abstract

In ballistic Josephson junctions the experimentally observed iv-characteristics deviate from the theoretically predicted behaviour. Recently, Heida et al. Phys. Rev. B **60**, 13135 (1999) discussed this problem and offered an explanation for the discrepancy. Considering this explanation, several contradictions to the authors' data as well as to other publications are shown.

In a recent paper, J. P. Heida et al. [1] report on the iv-characteristics of four ballistic superconductor-semiconductor-superconductor samples and focus on possible mechanisms for their observed low characteristic voltage (the $I_C \times R_N$ product). As many groups struggle with slow progress to fabricate optimized samples, where this parameter gets close to the theoretically predicted maximum value, any explanation why it may not be possible to reach this goal would be highly welcome. However, the explanation offered rises many questions, that need to be answered before concluding, that partly diffusive InAs layers are the key to explain the experimental findings.

The proper treatment of the InAs layers before the deposition of the Nb layers has been reported by many groups to be the most delicate fabrication step in order to achieve low interface barriers ([2] and Refs. 12-20). Using too weak Ar sputter cleaning, not all of the oxides on the surface are removed, while too strong cleaning may result in degradation of the mobility of the sample. Taking a not perfect interface into account [3], however, the reduction of the critical current has been theoretically explained by many authors (e.g. Refs. 10 and 11).

The first arising question is therefore related to the claim of perfect interfaces. Evidence for this could be established by analysis of subgap structures in the iv-characteristics or the excess current (e.g. using the OBTK-Model as an approximation). Without such evidence, a reduced critical current in fact is not a surprise and can be well explained by the established theories. To show measurements of the characteristics up to voltages of $2\Delta/e$ might be also helpful in order to extract the real normal resistance, which for a proper comparison cannot be approximated by the subgap resistance at low voltages. Especially the rather low critical temperature of the deposited Nb films for a thickness of 70 nm seems to indicate the opposite, namely that some kind of contamination occurred, which most likely makes it difficult to obtain a high quality interface.

As for the values for the critical current I_C measured for four different samples, I would appreciate to see this behaviour in a greater variety of samples before concluding that I_C is "independent of the junction length". There seems to be too large parameter spread to support such conclusion, especially when taking into account more data previously published by the same authors, that were measured at very similar samples [4]. According to the authors' explanation, any parameter spread (in particular true for sample "B" or "4") must be due to local differences in the properties of the diffusive InAs layer, as all interfaces are assumed to be ideal. Therefore the authors should (first) explain this unexpected high parameter spread. Taking into account the proper effective masses at the carrier concentration used [5], the coherence length is found to be about 250 nm and not 500 nm as claimed by the authors. Therefore none of the samples belongs to the short junction regime contrary to the authors' claim. This again shows the contradiction between the claimed result, that all samples are short junctions and might need to be further discussed.

The most important question, however, concerns the mechanism for the reduction of the critical current due to scattering events at the damaged InAs underneath the Nb layers. About 30 modes are assumed to be formed within the width of 700 nm and scattering between the modes is claimed to reduce the critical current. The scattering events however are not necessarily phase destructive, which is the mechanism to destroy Andreev bound states and to reduce the critical current. In order to support the authors' idea, a comparison of samples with different width W and correspondingly different number of modes would be

helpful to check the proposed $1/N$ behaviour. Samples studied by other groups ([6] and references 12-20) with much larger widths show in contradiction to the authors' explanation higher characteristic voltages in spite of the much larger number of modes. In addition, the authors only give an explanation for a reduced critical current and not for a reduced characteristic voltage.

Finally, the authors make one claim, which is not in accordance with recent publications. The authors should state their arguments: To my knowledge, it has never been shown, that the pairing interaction inside the normal conducting layer is (always) absent. As explained in the very first publications about this kind of Josephson junctions (e.g. Ref. 2), this is only a simplified assumption, used in most theoretical descriptions (except e.g. [7,8]). On the contrary, many experimental results indicate the opposite ([9,10] and Ref. 20), as the phonon-mediated interaction might not end abruptly at any interface.

In conclusion, more data are needed and obvious contradictions have to be discussed to find a correct description for this kind of ballistic Josephson junctions.

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